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(CORPORATE, AIR & MARITIME)**

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**A H-FRAME MODEL TO ASSIST IN DECISION MAKING FOR
THE FRIGATE LIFE EXTENSION PROGRAM**

BY

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OTTAWA, CANADA



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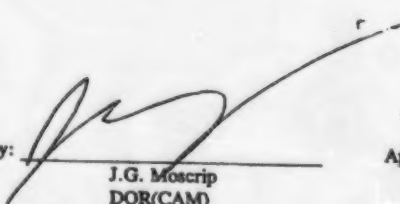
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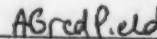
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ABSTRACT

Operational Research was tasked to provide support for the Frigate Life Extension (FELEX) Program. A hierarchical model was created using the Operational Research H-FRAME software. This model demonstrates the links from potential FELEX upgrades to various dimensions of performance. These performance dimensions are then linked to warfare areas, which are then linked to explicit operational scenarios. By providing a measure for each of these linkages, the impact upon the performance of the frigate in a number of scenarios can be visualized for each upgrade.

The final result of this project is not an authoritative measure of upgrade impact. Rather, it is an organized collection of the accumulation of expert opinion. This report demonstrates the areas where each upgrade has an impact, and providing some initial measure of the extent of this impact. The information can be used in providing a direction for future study, or to help justify decisions that have been made.

RÉSUMÉ

La Recherche opérationnelle a été chargée de fournir le soutien nécessaire au Projet de prolongation de la vie de l'équipement des frégates (FELEX). Un modèle hiérarchique a été mis sur pied à partir du logiciel H-FRAME de la Recherche opérationnelle. Ce modèle indique les liens qui existent entre les éventuelles améliorations au FELEX et les différents aspects de l'efficacité des frégates. Ces aspects sont ensuite associés à des zones de guerre, qu'on fait correspondre à des scénarios opérationnels précis. Le fait de déterminer une mesure pour chacun de ces liens permet d'observer, dans un certain nombre de situations, l'incidence de chaque amélioration sur l'efficacité des frégates.

L'objectif final de ce projet n'est pas de définir de façon précise l'incidence des améliorations, mais plutôt de regrouper de façon ordonnée l'opinion de divers spécialistes. L'utilité du projet consiste à indiquer sur quels aspects chaque amélioration aura une incidence et à donner une certaine idée de l'ampleur de cette incidence. Les renseignements ainsi obtenus serviront ensuite à orienter les études ultérieures et à justifier les décisions qui ont été prises.

EXECUTIVE SUMMARY

1. The Frigate Life Extension (FELEX) program is designed to extend the capability of the Canadian Halifax class frigates to the year 2030. In the intervening period, it is expected that the capability of any threat Canada could encounter would increase over time. In order to maintain their level of ability against these threats, the Canadian ships must be upgraded. The Director General Operational Research (DGOR) was asked to provide assistance in choosing the best upgrades to include in this program.
2. To support this project, a methodology was applied using the H-FRAME decision support software. This software permits the user to create a hierarchy, where the performance of each entity in the hierarchy is dependent on the performance of the entities in the layer immediately below. The user defines the relation between adjacent layers using boolean logic.
3. The FELEX methodology involved creating a five-layer hierarchy to model the decision process. At the lowest layer are the upgrades themselves. These are simple on/off measures, representing whether or not an upgrade is performed. The second layer consists of ship performance dimensions, representing specific activities that could be performed by a ship (eg: subsurface detection range). These are measured on a qualitative scale from Poor to Excellent. The third layer, represents the general warfare capabilities of the Canadian Navy, as performed by the frigate. These are also on a Poor to Excellent scale. The fourth layer is a set of departmental scenarios, representing a number of situations that could involve a frigate. These are also rated from Poor to Excellent, and represent the ability of the frigate to perform in each scenario. The fifth layer is an overall measure, giving an overall capability of the frigate, measured by the minimal performance of the frigate over all the scenarios. This hierarchy is summarized in Figure ES-1.

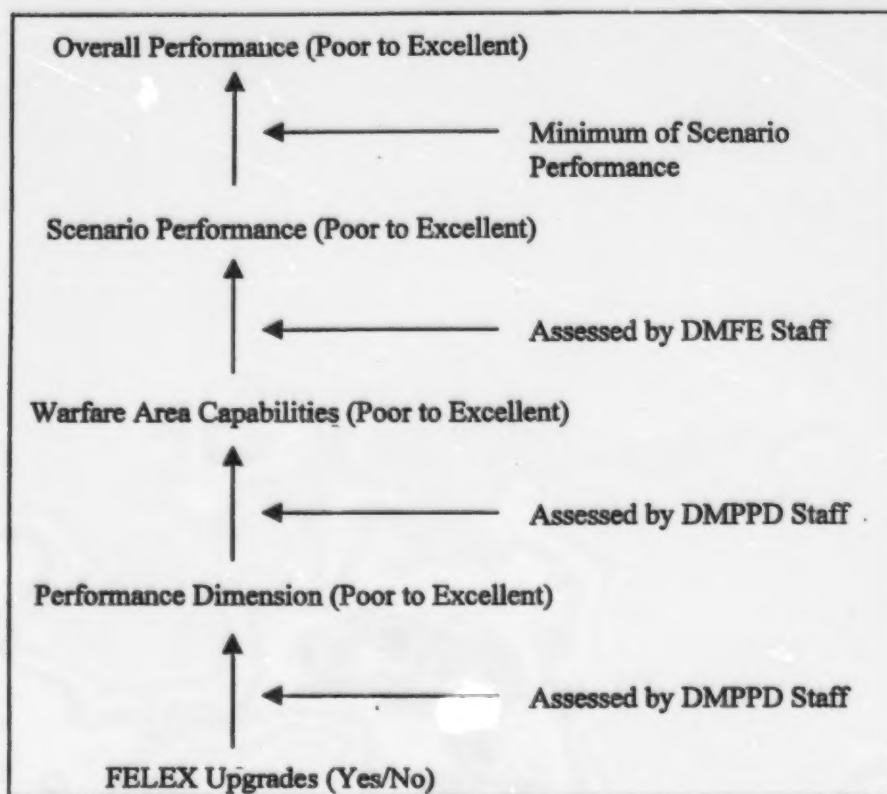


Figure ES - 1: H-FRAME Hierarchy Employed

4. The model was populated using expert opinion from a number of subject matter experts. It has the effect of taking the opinion from a number of experts and structuring it logically, thereby permitting conclusions to be drawn. These conclusions are then based upon the best expert opinion available, and can be logically justified when compared to other options.

5. The result of the model is a prioritized list of upgrades for the frigate. It was found that, according to the expert opinion, the frigate would have an overall Poor capability by the year 2030 if FELEX (or a similar program) is not carried out. The required upgrades to raise the capability to slightly higher levels are summarized in Table ES-I below.

TABLE ES - I
FELEX UPGRADE RECOMMENDATIONS

Desired Capability	Required Upgrades
Fair/Poor	Close In Weapons System upgrade Evolved Sea Sparrow Missile 3D Radar or Advance Phased Array Radar Ship Integrated Electronic Warfare Replacement Activity Stabilized Electro-Optical Sensor System Integrated Anti-Sub Warfare Sensor Suite NATO Tactical Display Naval Networks Global Broadcast System or Canadian Military Satellite Communications Communications upgrade
Fair	All of the Above + Medium Range Radar Advanced Phased Array Radar Navigational Radar upgrade

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A H-FRAME MODEL TO ASSIST IN DECISION MAKING FOR THE FRIGATE LIFE EXTENSION PROGRAM

INTRODUCTION

1. The goal of the Frigate Equipment Life Extension (FELEX) project is to maintain the capability of Canada's fleet of City class frigates into the 21st century. At present, the Naval opinion is that the City class frigates are a modern fleet, capable of meeting the challenges of the modern world. However, the world is always evolving and the potential challenges are consistently advancing. By the time the fleet is paid off by 2030, it is anticipated that the City class frigates will suffer a serious reduction in their capabilities. The principal reason for this change does not lie with the deterioration of the ships over time. The cause lies in the continuously improving threat. If the fleet is not improved, the ability of the ships to carry out potential missions will be seriously hampered.

2. There are a large number of options available for upgrade. Not surprisingly, there are more proposed upgrades than available funding. The Director General Operational Research (DGOR) was tasked to assist in the prioritization of equipment upgrades and to analyze the operational effects of these upgrades [Ref 1].

3. A handful of analyses were performed early in the upgrade selection process. A threat assessment was performed by DG Int to identify probable technological advancements in threats to the year 2025 [Ref 2]. An engineering study looked at the physical aspects of some of the proposed upgrades [Ref 3]. In addition, an Operational Research survey identified six likely scenarios of the 11 Departmental scenarios, and asked senior officers to prioritize warfare areas in which they felt the ability of the frigates had to be improved to adequately meet the stated goals of each scenario [Ref 4]. A previous Operational Research study identified a number of performance dimensions and warfare capabilities which the navy has to meet [Ref 5].

4. Following these initial assessments, a structure was put into place in which expert opinion is used to identify the effects of equipment upgrades on planned scenarios for the Canadian Navy. This structure uses the H-FRAME system [Ref 6] to demonstrate the impact of equipment upgrades on ship performance. These effects are propagated through various warfare capabilities, then applied to the six scenarios. In this manner, the eventual effect of an equipment upgrade on the overall operation of the frigate can be shown.

H-FRAME APPLICATION

5. The Hierarchical Framework for the Analysis of Mission Effectiveness (H-FRAME) is an application developed in DGOR. In this system, any number of layers, or hierarchies, are set up and the relation between each layer and the immediate layer below is specified. Using these relations, the resources spent on the lowest layer entities are percolated through the system, thereby demonstrating the resulting effectiveness of higher layer entities.

6. Each level in a H-Frame model consists of a number of entities. A number of effectiveness levels are associated with each entity. The effectiveness levels of each entity are defined in terms of the minimum requirements of the effectiveness of entities at the previous layer.

7. The user directly sets the effectiveness levels of the lowest layer of entities. This corresponds to ascribing various effectiveness levels to these entities through resource allocation, funding, proficiency, or any other appropriate measure of effectiveness. With higher layer entities, the effectiveness level depends on the definitions provided and the state of the entities in the next lowest layer. The associated effectiveness level is then determined as the highest level for which the defined lower layer requirements are true.

8. As an example, consider the hierarchy shown in Figure 1. This is a simple, three layered hierarchy. The first layer entities (left column) each have three effectiveness levels. For this example, the three available levels have been set to \$0, \$50K, and \$100K. These levels

represent the amount of financial resources devoted to each entity. The three entities at the first layer (Air, Surface, and Subsurface) have been assigned resource levels of \$100K, \$50K, and \$50K respectively.

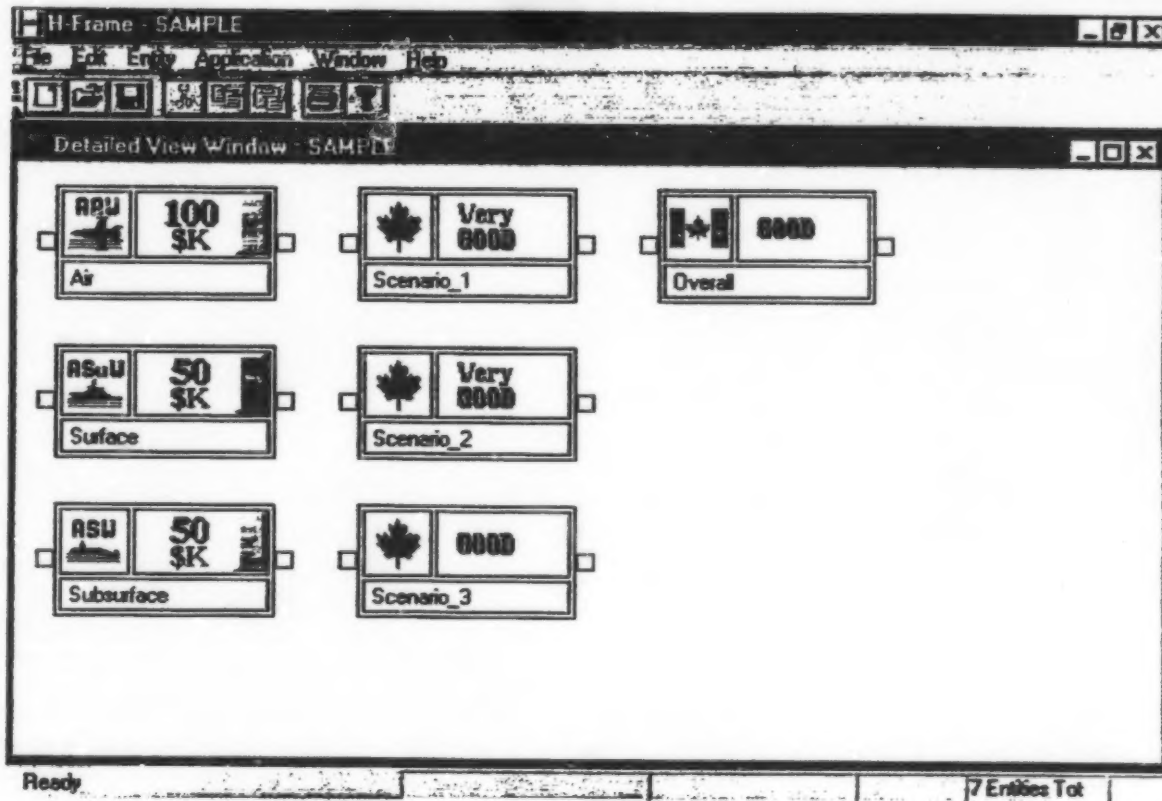


Figure 1: A Sample H-Frame Model

9. The entities in the second layer have four defined levels of effectiveness: Fair, Good, Very Good, and Excellent. For each effectiveness level of the second layer entities, a first layer requirement has been defined. For this example, the requirements for each level of effectiveness are given in Table 1.

TABLE I
EFFECTIVENESS LEVEL DEFINITIONS FOR LAYER 2 ENTITIES

	AAW Entity	ASuW Entity	ASW Entity
Scenario 1			
Excellent	\$100K	\$50K	\$100K
Very Good	\$100K	\$50K	\$0
Good	\$50K	\$50K	\$0
Fair	\$0	\$0	\$0
Scenario 2			
Excellent	\$100K	\$100K	\$100K
Very Good	\$50K	\$50K	\$50K
Good	\$50K	\$0	\$50K
Fair	\$0	\$0	\$0
Scenario 3			
Excellent	\$100K	\$100K	\$100K
Very Good	\$100K	\$100K	\$50K
Good	\$50K	\$50K	\$50K
Fair	\$0	\$0	\$0

10. With these definitions, Scenario 1, Scenario 2, and Scenario 3 have effectiveness levels of Very Good, Very Good, and Good, respectively. To see how this is derived, consider Scenario 1. In order to achieve an Excellent rating, AAW has to be allocated \$100K (which is met), ASuW has to be allocated \$50K (which is also met), and ASW has to be allocated \$100K (which is not met). Hence, the rating of Scenario 1 does not meet the conditions for the Excellent rating. However, a Very Good rating requires investments of \$100K, \$50K, and \$0 for AAW, ASuW, and ASW, respectively. These conditions are met, and as a result, Scenario 1 has a Very Good rating. This can be seen in Figure 1.

11. The third layer consists of a single entity, named Overall. The defined levels for this entity are the same as for the second layer: Fair, Good, Very Good, and Excellent. The definitions for each of these levels are specified as the lowest level of the second layer entities. Thus, in this example, Scenario 1 and Scenario 2 are both "Very Good", but Scenario 3 is "Good" resulting in the Overall entity having an effectiveness level of "Good".

12. The definitions presented in this example are fairly straight-forward: A specified effectiveness level is met if all of the defined conditions are met. However, the definitions can be more complex. With H-Frame, the definitions are specified using the Boolean "And" and "Or" connectors. The previous example used only the "And" connector. The definitions can be more complex when both the "And" and "Or" connectors are used.

13. The H-Frame software is also capable of performing analysis on the model in two manners. First, it can perform a savings analysis. Given an effectiveness level for an upper layer entity, it may be possible to preserve the effectiveness level of that entity while reducing the level of one or more entities at the first layer. For instance, in the model above, the effectiveness level of the Overall entity is Good. It may be possible to reduce the input level of some of the first layer entities and retain the Good rating of Overall. In fact, in this example, the Air investment can be reduced from \$100K to \$50K. If this were to be effected, the effectiveness of Scenario 1 is reduced to the Good level, Scenario 2 remains at Very Good, and Scenario 3 remains at Good. However, the rating of Overall remains at Good. Thus, an entity has been found for which a saving can be realized without changing the overall performance.

14. The second type of analysis is an enhancement analysis. This displays the changes required to the inputs in order to raise the effectiveness of a given entity to a specified level. For instance, in the example, what is required to raise the performance of the Overall entity to the Very Good level? The program determines that the Air and Surface entities must be set to \$100K and Subsurface must be \$50K. This sets all three Scenario entities to Very Good, and as a result, the Overall entity is enhanced to the Very Good level.

USING H-FRAME WITH FELEX

15. A H-FRAME hierarchy of five layers was used to analyze the effect of FELEX upgrades on the overall effectiveness of the City class frigates. The five layers are Upgrades, Performance Dimensions, Capabilities, Scenarios, and Overall. Tables II through V below list the entities of

each layer of this hierarchy. The full list of dependencies in the hierarchy is found in Annex A. A glossary of these abbreviations is found in Annex D.

TABLE II
FELEX UPGRADE ENTITIES

57mm Gun Replacement	Small Arms	CIWS (Phalanx)
CIWS (RAM)	ESSM	Area AAW Missile
Harpoon Missile	PGM	STIR
Medium-Range Radar	3D Radar	2D Radar
APAR	SIERA	ACES
SIRIUS	SEOSS	Laser Warning Receiver
CEC	Shipborne HFSWR	IASWSS
Ship Signature	MSPPS	Mine Avoidance Software
Navigation Radar	Comms	Biological Detector
NTD	Naval Networks	GBS
CANMILSATCOM		

TABLE III
PERFORMANCE DIMENSION ENTITIES

ASW Sensitivity (Littoral)	ASW Sensitivity (Deep)	ASW Classification Accuracy (Littoral)
ASW Classification Accuracy (Deep)	ASW Classification Delay	ASW Destructive Effect (Littoral)
ASW Destructive Effect (Deep)	Torpedo Decoy Effectiveness	Torpedo Detection
ASuW Counter Measure Resistance	ASuW Destroy Effectiveness	ASuW Destroy Range
ASuW Classification Time (Littoral)	ASuW Classification Time (Open Ocean)	ASuW Classification Accuracy (Littoral)
ASuW Classification Accuracy (Open Ocean)	ASuW Classification Range (Littoral)	ASuW Classification Range (Open Ocean)
ASuW Detection Range (Littoral)	ASuW Detection Range (Open Ocean)	ASuW Sensor Sensitivity (Littoral)
ASuW Sensor Sensitivity (Open Ocean)	AAW Destruction Effect	AAW Destruction Range
AAW ID Delay	AAW ID Reliability	AAW ID Range
AAW Track Continuity	AAW Detection Range	AAW CM Resistance
Data Fusion	Information Dissemination	Presentation and Display
Maintain Communications	National Connectivity	International Connectivity
3D Information	ESM	Mine Detection Rate
Mine Classification Rate	Mine Neutralization Rate	Vessel Boarding
Vessel Warn/Stop Effect	Vessel Warn/Stop Safety	Nuclear Detection
Chemical Detection	Biological Detection	Chemical ID
Biological ID	Nuclear Ops	Chemical Ops
Biological Ops	Nuclear Cleaning	Chemical Cleaning
Biological Cleaning		

TABLE IV
CAPABILITY ENTITIES

Detect/Class Sub (National)	Detect/Class Sub (International)	Localize/Track Sub (National)
Localize/Track Sub (International)	Destroy Sub	Counter Sub Attack
Classify/ID Surface	Destroy Surface	Classify/ID Air
Defend Air	Detect Mine (National)	Detect Mine (International)
Neutralize Mine	Warn/Stop Vessels	Board Vessels

TABLE V
SCENARIO ENTITIES

Counter Smuggling	Naval Embargo	Mineral Dispute
Peace Support	Can/US Defence	NATO Defence

Upgrades

16. The entities in the Upgrades layer of the hierarchy (Table II) are those upgrades being considered for the FELEX project. The associated effectiveness measure is a simple yes/no measure, indicating whether or not the upgrade is to be considered in the overall model.

Performance Dimensions

17. The entities in the Performance Dimension layer of the hierarchy (Table III) are individual areas of frigate performance which affect the overall capability of the ship. They can be roughly grouped into a number of categories: ASW, ASuW, AAW, C2, MW, Constabulary, and NBC. Each dimension is to be considered in isolation of all others. For each entity in this layer, the defined levels of effectiveness are Excellent, Good, Fair, and Poor, defined as:

Excellent:	Performs task against all credible threats in all credible situations.
Good:	Performs task against likely threats in likely situations.
Fair:	Unable to perform task against some likely threats or in some likely situations
Poor:	Unable to perform task against most threats in most situations.

In addition to these defined levels, there are intermediate levels that can be used to allow for uncertainty: Excellent/Good, Good/Fair, and Fair/Poor.

18. Each performance dimension entity is linked to a number of upgrades. For each link, the performance dimension effectiveness with this upgrade is determined through the use of expert opinion. The inputs for each level of Performance Dimension are determined by answering the question: "Which Upgrades to the current frigate would be required to provide this level of effectiveness?".

Capabilities

19. The effectiveness of each entity in the Capability layer of the hierarchy (Table IV) is similar to the Performance Dimensions layer: Excellent, Good, Fair, and Poor, with intermediate values Excellent/Good, Good/Fair, and Fair/Poor. Capabilities are warfare areas, similar to the previous layer, but broader in scope. Each entity in this layer is linked to the Performance Dimension layer. For each Capability effectiveness level, the question is asked: "What Performance Dimensions are required to provide Capability at this level of effectiveness, and what level must these Dimensions achieve to provide this level of effectiveness?" The definitions of each level of effectiveness are the same as in the first stage.

Scenarios

20. The entities in the Scenarios layer (Table V) represent situations the Canadian frigates must be prepared to encounter. These six Scenarios are a subset of a set of scenarios currently being created by the Department for planning use. The six chosen scenarios are those that

contain a maritime component. The effectiveness levels for this layer are the same as for the previous two layers: Excellent, Good, Fair, and Poor, with intermediate values Excellent/Good, Good/Fair, and Fair/Poor, and the same definitions.

Overall

21. The final layer consists of a single entity named Overall. This entity initially reflects the lowest scenario performance, thereby giving equal weight to all scenarios. However, this entity can also be altered to reflect the strategic situation being considered by providing more weight to one or more scenarios. Alternatively, this layer can be disregarded, and each of the six scenarios considered separately.

POPULATING THE H-FRAME MODEL

Upgrades to Performance Dimensions

22. The Performance Dimensions were sorted into a number of groups, and subject matter expert input was solicited in each area. For the Upgrade to Performance Dimension input, subject matter experts from the sponsoring directorate (DMPPD) provided the required input. For each group of Performance Dimensions, an associated officer from DMPPD was identified and provided the required input. During these discussions, a number of other potential upgrades and enhancements were identified and incorporated into Table II. At the same time, the list of Performance Dimensions was modified to better reflect the individual aspects of each warfare area. The requirements for each level of performance provided by the experts are given in Annex A. The remainder of this section will discuss areas of concern, which were identified by the experts.

23. For these judgements, the time factor is important. The experts were asked to judge not only the effect of an upgrade on ship performance today, but also on ship performance in thirty years. This requires a degree of "crystal ball gazing", but it is also supported by an intelligence estimate of the changing threat over the next thirty years [ref 2].

24. **Constabulary.** This group consists of three entities, namely Boarding Ability, Warn/Stop Effect, and Warn/Stop Safety. Concerns in this area were centered on the threatening appearance of the frigate. It was felt that the visible weapons, either organic to the ship or carried by a boarding party, would not be adequate to deter resistance by a well-armed foe.

25. **Mine Warfare.** This is an area that potentially permeates almost all other aspects. An inability to operate in mined waters hampers mobility to the point that assigned tasks cannot be completed. However, even though mine warfare has an impact on performance of a force as a whole, it is normally considered a totally separate aspect of warfare. The tediously slow speed of anti-mine operations necessitates its execution only in a secure environment except under extreme circumstances. Ships carrying out anti-mining are vulnerable due to their limited mobility in a minefield, and thus are dependent on exterior vessels for their own safety. However, as a result of this assumption, the time required to detect and/or clear a minefield is not a major concern. It is assumed that there is time available to perform the task. The principal concern is the availability of the proper equipment to do the job.

26. In terms of FELEX, mine warfare is not a major consideration. The frigates are not designed for mine operations, and projected upgrades will not concentrate on this area. However, it has been included for completeness. In fact, as will be seen in the results, if this aspect is considered as an essential capability for the frigate, performance declines solely as a result of including Mine Warfare.

27. **ASW.** In this area, it was felt that the frigates have a good capability, but that will be decreasing drastically in the future without upgrades. However, the point that was emphasized strongly in this area was that the command and control must keep pace. If the upgrades are performed without corresponding command and control upgrades, performance will continue to deteriorate. The judgements included in the FELEX H-Frame model incorporate this assumption.

28. **NBC.** Since Canada does not perform offensive NBC operations, this area is limited to defensive measures. In any NBC environment, the frigates have very good detection ability, although it is expected to decrease over time. The ability to operate in a contaminated environment is mainly a result of the Citadel capabilities of the ship, which keeps contaminated air outside the ship and clean air inside. This allows the ship to operate normally with the exception of above-deck operations. Thus, the largest effect is on helicopter operations, which are essentially impossible in a contaminated environment.

29. Under FELEX, there is only a single upgrade considered in the NBC area. As a result, this area is not a major concern, although the effects of this upgrade can be seen with the model.

Performance Dimensions to Warfare Areas

30. For this layer, experts from DMPPD provided the input. In general, the respondents were comfortable with the scale provided, and felt confident in the answers provided. These results are given in Annex B.

Warfare Areas to Scenarios

31. For this layer, experts from Director Maritime Force Employment (DMFE) provided the input. Six surveys were completed and returned, and the results are presented in Annex C. The ranks of the participants ranged from Naval Lieutenant to Commander. For this stage, the experts expressed less confidence in their assessments. In many cases, the scenarios, as presented, required a number of assumptions to be made, such as whether or not hostile submarines were present. Nevertheless, when the surveys were returned, a simple averaging of the results provided agreement in many instances, and meetings with the four of the six participants yielded the consensus presented in Annex C.

RESULTS

32. This process produced a list of upgrades and tied their effects into the ability of the frigates to perform their role in a number of scenarios, as summarized in the previous section. These links were derived through the opinions of a number of experts in various warfare areas in DMPPD and DMFE. The participants, as a result of their experience and postings, are considered relevant experts in the field, and therefore qualified to provide judgements on these areas.

33. As mentioned in the introduction, naval staff generally feels that the Halifax class frigate is a capable ship when measured against the possible threats of today. However, the expert judgements provided do not bear out that opinion. When the judgements are tabulated, the frigate is given a Poor rating in today's environment.

34. Not surprisingly, without a FELEX upgrade, the overall performance of the frigate in the 2030 time frame remains rated as Poor. All of the scenarios rate Poor in this instance. In fact, with the assessments as given, it is impossible to raise the overall capability any higher than Fair/Poor. However, detailed examination of the completed model shows that the only entity preventing a higher rating is the Detect Mines (I) entity. The ability to detect mines for the scenarios was one of the debated assessments. Some experts felt that it was not the role of the frigate to detect mines, and that there would be other assets to accomplish the task. The other experts thought was that the frigate was very susceptible to mines without at least some detection ability. With this in mind, the model was modified to remove the mine detection and neutralization aspect. The effect was to raise the overall performance up to the level of Fair.

35. Once the Mine Warfare capability is excluded, several upgrades are still required to simply raise the overall level from Poor to Fair/Poor for all scenarios. The enhancements required are given in Table VI.

TABLE VI
REQUIRED UPGRADES

Desired Capability	Required Upgrades
Fair/Poor	Close In Weapons System upgrade Evolved Sea Sparrow Missile 3D Radar or Advance Phased Array Radar Ship Integrated Electronic Warfare Replacement Activity Stabilized Electro-Optical Sensor System Integrated Anti-Sub Warfare Sensor Suite NATO Tactical Display Naval Networks Global Broadcast System or Canadian Military Satellite Communications Communications upgrade
Fair	All of the Above + Medium Range Radar Advanced Phased Array Radar Navigational Radar upgrade

36. When the upgrades required to reach a certain level, as specified in Table VI are activated, the actual performance across the scenarios can vary. For instance, to reach an overall level of Fair, all the upgrades as specified above are required. However, they bring the performance of three scenarios to Fair, and the other three scenarios to Good/Fair. Table VII summarizes the performance by scenario when the specified upgrades are activated.

TABLE VII
SCENARIO RATINGS FOR GIVEN OVERALL RATING

Overall	Poor	Fair/Poor	Fair
Scenario 1: Countering Smugglers	Poor	Fair/Poor	Good/Fair
Scenario 2: Naval Embargo	Poor	Fair/Poor	Good/Fair
Scenario 3: Mineral Dispute	Poor	Fair/Poor	Good/Fair
Scenario 4: Peace Support	Poor	Fair	Fair
Scenario 5: Canada/US Defence	Poor	Fair/Poor	Fair
Scenario 6: NATO Defence	Poor	Fair/Poor	Fair

FUTURE ANALYSIS POSSIBILITIES

37. The information as entered into the H-Frame model was collected through a number of individual interviews with subject matter experts. As such, it represents a collection of viewpoints, each with potentially different interpretations on the definition of each capability level. In order to increase the confidence in the results, it is essential to bring together a number of people who can work together to form a consensus on the ratings, instead of relying on the input of a single subject matter expert.

38. Within the list of upgrades, there are some instances of equipment that is not fully developed, such as APAR and MSPPS. In these instances, the evolving capabilities cannot be completely understood, even by the experts. Although expert opinion is still the best way to make these judgements, the confidence expressed by the experts in their own judgements is somewhat reduced.

39. Currently, there is an initiative underway in the Directorate of Strategic Planning (DGSP) to draw linkages between the Departmental scenarios (a subset of which was used here) and required military capability. Part of this initiative involves compiling a Task List for the Canadian forces, and a list of required capabilities. It is strongly recommended that the results of the DGSP initiative be incorporated into this H-Frame model.

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UPGRADES TO PERFORMANCE DIMENSIONS

1. For each performance dimension, the experts were asked to estimate the current level of the frigate, the level of the frigate in 2030 if no upgrades are made, and the impact of each upgrade on the 2030 level of performance.

ASW

ASW Sensor Sensitivity - Littoral (Current Fair, 2030 Poor):

Good: IASWSS and MSPPS

Good/Fair: IASWSS

ASW Sensor Sensitivity - Deep (Current Good, 2030 Fair):

Excellent/ Good: IASWSS and MSPPS

Good: IASWSS

ASW Classification Accuracy - Littoral (Current Fair/Poor, 2030 Poor):

Good: IASWSS and MSPPS

Good/Fair: IASWSS

ASW Classification Accuracy - Deep (Current Good, 2030 Fair):

Excellent/ Good: IASWSS and MSPPS

Good: IASWSS

ASW Classification Delay (Current Excellent/Good, 2030 Poor):

Excellent/ Good: IASWSS and MSPPS

Good: IASWSS

ASW Destroy Effectiveness - Littoral (Current Fair, 2030 Poor):

No changes

ASW Destroy Effectiveness - Deep (Current Good, 2030 Fair):

No changes

ASW Decoy Effectiveness (Current Poor, 2030 Good/Fair):

No change (Assumes Torpedo Defence Project and NIXIE Upgrade will be implemented before FELEX).

ASW Torpedo Detection (Current Fair, 2030 Poor):

Good: IASWSS

ASuW

CM Resistance (Current Good, 2030 Fair):

Good: SIRIUS

Destroy Effectiveness (Current Good, 2030 Fair/Poor):

Excellent/Good: CIWS, ESSM, Harpoon

Good/Fair: ESSM, CIWS

Destroy Range (Current Excellent/Good, 2030 Fair):

Excellent/Good: CIWS, Harpoon, ESSM, STIR, APAR, SIRIUS

Good/Fair: ESSM, CIWS

Classification Time - Littoral (Current Fair, 2030 Poor):

Good/Fair: SIERA, SEOSS

Fair: SIERA or SEOSS

Classification Time - Open (Current Good/Fair, 2030 Fair/Poor):

Good/Fair: SIERA, SEOSS

Fair: SIERA or SEOSS

Classification Accuracy - Littoral (Current Good/Fair, 2030 Fair/Poor):

Good: SIERA, SEOSS

Good/Fair: SIERA or SEOSS

Classification Accuracy - Open (Current Good/Fair, 2030 Fair/Poor):

Good: SIERA, SEOSS

Good/Fair: SIERA or SEOSS

Classification Range - Littoral (Current Good, 2030 Fair/Poor):

Good: SIERA, SEOSS

Good/Fair: SIERA or SEOSS

Classification Range - Open (Current Good/Fair, 2030 Fair/Poor):

Excellent/Good: SIERA, SEOSS

Good: SIERA or SEOSS

Detection Range - Littoral (Current Fair, 2030 Poor):

Excellent/Good: APAR, STIR, SEOSS

Good: STIR, SEOSS

Good/Fair: STIR or SEOSS

Detection Range - Open (Current Excellent/Good, 2030 Good/Fair):

Excellent/Good: APAR, SEOSS, 3D, 2D

Good: APAR, SEOSS

Sensor Sensitivity - Littoral (Current Good/Fair, 2030 Poor):

Excellent/Good: STIR, SEOSS, APAR

Good: STIR, SEOSS

Good/Fair: APAR

Fair: STIR or SEOSS

Sensor Sensitivity - Open (Current Good, 2030 Fair):

Good: 3D, 2D, APAR, SEOSS

Good/Fair: APAR, SEOSS

AAW

Destroy Effect (Current Excellent/Good, 2030 Fair/Poor):

Good: ESSM

Destroy Range (Current Good, 2030 Poor):

Excellent/Good: APAR, CIWS, ESSM, STIR

Good/Fair: APAR, CIWS, ESSM

Fair: ESSM, CIWS

Identification Delay (Current Excellent/Good, 2030 Good/Fair):

Excellent/Good: APAR, SEOSS, 2D, 3D, SIERA, STIR

Good: APAR, SEOSS, 2D

Identification Reliability (Current Good, 2030 Fair/Poor):

Good: APAR, SEOSS

Fair: APAR or SEOSS

Identification Range (Current Excellent/Good, 2030 Fair):

Excellent/Good: 3D, APAR, SIRIUS, SEOSS

Good/Fair: APAR, SEOSS

Track Continuity (Current Excellent/Good, 2030 Good/Fair):

Excellent/Good: STIR, 3D, 2D, APAR, SIRIUS

Good: APAR, SIRIUS

Detect Range (Current Excellent/Good, 2030 Good/Fair):

Excellent/Good: 3D, 2D, APAR, SIRIUS, SEOSS

CM Resistance (Current Excellent/Good, 2030 Good/Fair):

Excellent/Good: ESSM

Command and Control

Data Fusion (Current Fair, 2030 Poor):

Good/Excellent: Naval Networks

Information Dissemination (Current Fair, 2030 Poor):

Excellent: NTD, Naval Networks

Presentation and Display (Current Fair, 2030 Poor):

Excellent: NTD

Maintain Communications (Current Fair, 2030 Poor):

Good: Naval Networks, GBS or CANMILSATCOM

National Connectivity (Current Fair/Poor, 2030 Poor):

Good: CANMILSATCOM or GBS

International Connectivity (Current Fair, 2030 Poor)

Good: CANMILSATCOM or GBS

3D Info (Current Poor, 2030 Poor):

Good: 3D Radar or APAR, NTD

ESM (Current Fair, 2030 Poor):

Good: NTD

Mines

Mine Detection Rate (Current Fair/Poor, 2030 Poor):

Good: SEOSS, Ship Signature, and Sonar and Avoidance Software

Mine Classification Rate (Current Poor, 2030 Poor):

No change (Currently no capability).

Mine Neutralization Rate (Current Poor, 2030 Poor):

No change (Currently no capability).

Constabulary

Vessel Boarding Ability (Current Good, 2030 Fair):

Good: Small Arms, Medium Range Radar, Short Range Nav Radar,
Comms

Vessel Warn/Stop Effect (Current Good/Fair, 2030 Fair/Poor):

Excellent/Good: 57 mm Gun Replacement

Good: Medium Range Radar, Short Range Nav Radar, Comms, CIWS

Vessel Warn/Stop Safety (Current Fair, 2030 Poor):

Good: 57 mm Gun Replacement, Small Arms, PGM, CIWS, Comms.

Fair: Comms.

NBC

Nuclear Detect (Current Good, 2030 Good):

No change.

Chemical Detect (Current Good, 2030 Poor):

No change.

Biological Detect (Current Good, 2030 Poor):

Poor: Biological Detector.

Chemical Identify (Current Good, 2030 Fair):

No change.

Biological Identify (Current Fair, 2030 Poor):

Poor: Biological Detector.

Nuclear Operations (Current Good, 2030 Good):

No change.

Chemical Operations (Current Good, 2030 Fair):

No change.

Biological Operations (Current Fair, 2030 Poor):

Good: Biological Detector.

Nuclear Cleaning (Current Good, 2030 Good):

No change.

Chemical Cleaning (Current Fair, 2030 Fair):

No change.

Biological Cleaning (Current Fair, 2030 Fair):

No change.

PERFORMANCE DIMENSIONS TO WARFARE AREAS

1. In this area of the model, participants were asked to draw the connections between general warfare areas and specific performance dimensions. The first question was to identify the theoretically maximum capability level in each warfare area. Then, for each warfare area, the participant was asked to identify the performance dimensions which impact on that area, and what level of capability is required to reach the maximum capability level. Using this maximum, the requirements for the lower capability levels were reduced step-wise until the lowest rating was reached. The maximum capability and required performance are outlined below.

ASW

Detect/Classify Sub - National (Good)

Classification Delay:	Excellent
Sensor Sensitivity (L):	Excellent/Good
Sensor Sensitivity (D):	Excellent/Good
Classification Accuracy (L):	Good
Classification Accuracy (D):	Good
Connectivity (N):	Excellent/Good

Detect/Classify Sub - International (Good)

Classification Delay:	Excellent
Sensor Sensitivity (L):	Excellent/Good
Sensor Sensitivity (D):	Excellent/Good
Classification Accuracy (L):	Good
Classification Accuracy (D):	Good
Connectivity (I):	Excellent/Good

Localize/Track Sub - National (Excellent)

Classification Delay:	Excellent
Sensor Sensitivity (L):	Excellent/Good
Sensor Sensitivity (D):	Excellent/Good
Classification Accuracy (L):	Excellent
Classification Accuracy (D):	Excellent
Connectivity (N):	Excellent

Localize/Track Sub - International (Excellent):

Classification Delay:	Excellent
Sensor Sensitivity (L):	Excellent/Good
Sensor Sensitivity (D):	Excellent/Good
Classification Accuracy (L):	Excellent
Classification Accuracy (D):	Excellent
Connectivity (I):	Excellent

Destroy Submarine (Good):

Classification Delay:	Excellent
Sensor Sensitivity (L):	Excellent
Sensor Sensitivity (D):	Excellent
Classification Accuracy (L):	Excellent
Classification Accuracy (D):	Excellent
Connectivity (N):	Excellent
Connectivity (I):	Excellent
Destroy Effect (D):	Excellent
Destroy Effect (L):	Excellent

Counter Underwater Attack (Good):

Sensor Sensitivity (L):	Excellent/Good
Sensor Sensitivity (D):	Excellent/Good
Classification Accuracy (L):	Excellent
Classification Accuracy (D):	Excellent
Connectivity (N):	Excellent
Connectivity (I):	Excellent

Decoy Effectiveness:	Excellent
Torpedo Detection:	Excellent

ASuW

Classify/ID Surface Vessels (Excellent/Good)

Sensor Sensitivity:	Good
Detection Range:	Excellent/Good
Classification Range:	Excellent/Good
Classification Accuracy:	Good
Classification Time:	Good
Data Fusion:	Good
Information Dissemination:	Excellent
Presentation and Display:	Excellent/Good
Maintain Communications:	Excellent/Good
National Connect:	Excellent/Good
International Connect:	Excellent/Good
ESM:	Excellent/Good

Destroy Surface Vessel (Good)

Sensor Sensitivity:	Good
Detection Range:	Excellent/Good
Classification Range:	Excellent/Good
Classification Accuracy:	Excellent/Good
Classification Time:	Good
Destroy Range:	Good
Destroy Effect:	Excellent/Good
Data Fusion:	Good
Information Dissemination:	Excellent
Presentation and Display:	Excellent/Good
Maintain Communications:	Excellent/Good
National Connect:	Excellent/Good

International Connect:	Excellent/Good
ESM:	Excellent/Good
CM Resistance:	Good

AAW

Classify/ID Aircraft/ASM (Excellent/Good)

Detection Range:	Excellent/Good
Track Continuity:	Excellent/Good
Identification Range:	Excellent/Good
Identification Reliability:	Good
Identification Delay:	Good
Data Fusion:	Good
3D Information:	Excellent/Good
Information Dissemination:	Excellent
Presentation and Display:	Excellent/Good
Maintain Communications:	Excellent/Good
National Connect:	Excellent/Good
International Connect:	Excellent/Good
ESM:	Excellent/Good

Defend Aircraft/ASM (Good)

Detection Range:	Excellent/Good
Track Continuity:	Excellent/Good
Identification Range:	Excellent/Good
Identification Reliability:	Excellent/Good
Identification Delay:	Excellent/Good
Destroy Range:	Excellent/Good
Destroy Effect:	Excellent/Good
Data Fusion:	Good
3D Information:	Excellent/Good
Information Dissemination:	Excellent

Presentation and Display:	Excellent/Good
Maintain Communications:	Excellent/Good
National Connect:	Excellent/Good
International Connect:	Excellent/Good
ESM:	Excellent/Good
CM Resistance:	Excellent/Good

Mine Warfare

Detect Mines - National (Good)

Connectivity National:	Excellent
Biological Detection:	Excellent
Chemical Detection:	Excellent
Biological Operations:	Excellent
Chemical Operations:	Excellent
Mine Detection Rate:	Good
Mine Classification Rate:	Good

Detect Mines - International (Fair)

Connectivity International:	Excellent
Biological Detection:	Excellent
Chemical Detection:	Excellent
Biological Operations:	Excellent
Chemical Operations:	Excellent
Mine Detection Rate:	Good
Mine Classification Rate:	Good

Neutralize Mines (Fair)

Connectivity National:	Excellent
Connectivity International:	Excellent
Biological Detection:	Excellent
Chemical Detection:	Excellent
Biological Operations:	Excellent

Chemical Operations:	Excellent
Mine Detection Rate:	Good
Mine Classification Rate:	Good
Mine Neutralize Rate:	Good

Constabulary

Warn/Stop Surface Vessels (Excellent)

Warn/Stop Effectiveness	Excellent
Warn/Stop Safety	Excellent
ASuW Detect Range	Excellent/Good
ASuW Classify Range	Excellent/Good
ASuW Classify Accuracy	Excellent/Good
ASuW Classify Timeliness	Excellent/Good
ASuW Destroy Range	Fair
ASuW Destroy Effect	Fair

Board Surface Vessels (Excellent)

Board Ability	Excellent
Warn/Stop Effectiveness	Excellent
Warn/Stop Safety	Excellent
ASuW Detect Range	Excellent/Good
ASuW Classify Range	Excellent/Good
ASuW Classify Accuracy	Excellent/Good
ASuW Classify Timeliness	Excellent/Good
ASuW Destroy Range	Fair
ASuW Destroy Effect	Fair

WARFARE AREAS TO SCENARIOS

Countering Smugglers (Excellent):

Detect/Class Sub (N):	Poor/Not Req'd
Detect/Class Sub (I):	Poor/Not Req'd
Localize/Track Sub (N):	Poor/Not Req'd
Localize/Track Sub (I):	Poor/Not Req'd
Destroy Sub:	Poor/Not Req'd
Counter UW Attack:	Poor/Not Req'd
Class/ID Surface:	Excellent
Destroy Surface:	Poor/Not Req'd
Class/ID Air:	Excellent
Defend Air:	Fair
Detect Mines (N):	Poor/Not Req'd
Detect Mines (I):	Poor/Not Req'd
Neutralize Mines:	Poor/Not Req'd
Warn/Stop:	Excellent
Board Vessels:	Excellent

Naval Embargo (Excellent):

Detect/Class Sub (N):	Good
Detect/Class Sub (I):	Good
Localize/Track Sub (N):	Good
Localize/Track Sub (I):	Good
Destroy Sub:	Poor/Not Req'd
Counter UW Attack:	Good
Class/ID Surface:	Excellent/Good
Destroy Surface:	Good

Class/ID Air:	Excellent/Good
Defend Air:	Good
Detect Mines (N):	Poor/Not Req'd
Detect Mines (I):	Good
Neutralize Mines:	Good/Fair
Warn/Stop:	Excellent
Board Vessels:	Excellent

Mineral Dispute (Excellent):

Detect/Class Sub (N):	Excellent/Good
Detect/Class Sub (I):	Excellent/Good
Localize/Track Sub (N):	Excellent/Good
Localize/Track Sub (I):	Excellent/Good
Destroy Sub:	Poor/Not Req'd
Counter UW Attack:	Good
Class/ID Surface:	Excellent
Destroy Surface:	Good/Fair
Class/ID Air:	Excellent/Good
Defend Air:	Good
Detect Mines (N):	Good
Detect Mines (I):	Good
Neutralize Mines:	Good/Fair
Warn/Stop:	Excellent
Board Vessels:	Excellent

Peace Support (Excellent/Good):

Detect/Class Sub (N):	Excellent/Good
Detect/Class Sub (I):	Excellent/Good
Localize/Track Sub (N):	Excellent/Good
Localize/Track Sub (I):	Excellent/Good
Destroy Sub:	Good
Counter UW Attack:	Good
Class/ID Surface:	Excellent

Destroy Surface:	Excellent/Good
Class/ID Air:	Excellent
Defend Air:	Excellent/Good
Detect Mines (N):	Poor/Not Req'd
Detect Mines (I):	Good
Neutralize Mines:	Good/Fair
Warn/Stop:	Excellent/Good
Board Vessels:	Good

Canada/US Defence (Excellent/Good):

Detect/Class Sub (N):	Excellent
Detect/Class Sub (I):	Excellent
Localize/Track Sub (N):	Excellent/Good
Localize/Track Sub (I):	Excellent
Destroy Sub:	Good/Fair
Counter UW Attack:	Excellent/Good
Class/ID Surface:	Excellent
Destroy Surface:	Excellent
Class/ID Air:	Excellent
Defend Air:	Excellent
Detect Mines (N):	Excellent
Detect Mines (I):	Excellent
Neutralize Mines:	Good
Warn/Stop:	Excellent
Board Vessels:	Good

NATO Defence (Excellent/Good):

Detect/Class Sub (N):	Excellent/Good
Detect/Class Sub (I):	Excellent/Good
Localize/Track Sub (N):	Excellent/Good
Localize/Track Sub (I):	Excellent/Good
Destroy Sub:	Good
Counter UW Attack:	Excellent/Good

Class/ID Surface:	Excellent
Destroy Surface:	Good
Class/ID Air:	Excellent
Defend Air:	Good
Detect Mines (N):	Excellent/Good
Detect Mines (I):	Excellent/Good
Neutralize Mines:	Good/Fair
Warn/Stop:	Excellent
Board Vessels:	Good

LIST OF ABBREVIATIONS

AAW	Anti-Air Warfare
APAR	Advanced Phased Array Radar
ASuW	Anti-Surface Warfare
ASW	Anti-Sub Warfare
CANMILSATCOM	Canadian Military Satellite Communications
CEC	Cooperative Engagement Capability
CIWS	Close In Weapons System
CIWS (RAM.	Close In Weapons System Rolling Airframe Missile
ELINT	Electronic Intelligence
ESSM	Evolved Sea Sparrow Missile
GBS	Global Broadcast System
HFSWR	High Frequency Surface Wave Radar
IASWSS	Integrated Anti Submarine Warfare Sonar Suite
MSPPS	Maritime Sensor Performance Prediction System
MW	Mine Warfare
NTD	NATO Tactical Display
PGM	Precision Guided Munitions
SEOSS	Stabilized Electro-Optical Sensor System
SIERA	Ships Integrated Electronic Warfare Replacement Activity
SIRIUS	A product name for an Infra Red Search and Track/ Detection (IRSTD) system
STIR	Search Track Infra Red

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Operational Research was tasked to provide support for the Frigate Life Extension (FELEX) Program. A hierarchical model was created using the Operational Research H-FRAME software. This model demonstrates the links from potential FELEX upgrades to various dimensions of performance. These performance dimensions are then linked to warfare areas, which are then linked to explicit operational scenarios. By providing a measure for each of these linkages, the impact upon the performance of the frigate in a number of scenarios can be visualized for each upgrade.

The final result of this project is not an authoritative measure of upgrade impact. Rather, it is an organized collection of the accumulation of expert opinion. This report demonstrates the areas where each upgrade has an impact, and providing some initial measure of the extent of this impact. The information can be used in providing a direction for future study, or to help justify decisions that have been made.

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